EORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[x] ORIGINAL [ ] REVISION NO. ______

roject No. A-3468 GTRI/~~XXX~~ DATE 2/4/83

roject Director: J. D. Echard ~~XXXXX~~/Lab RAIL-AD

ponsor: U. S. Army ERADCOM, Ft. Monmouth, NJ

ype Agreement: Purchase Order No. DAAK20-83-M-0208

ward Period: From 1/21/83 To 4/20/83 (Performance) --- (Reports)

ponsor Amount: Total Estimated: $ 15,976 Funded: $ 15,976

ost Sharing Amount: $ None Cost Sharing No: N/A

itle: Airborne Test Bed Development Program

DMINISTRATIVE DATA

OCA Contact William F. Brown x-4820

) Sponsor Technical Contact:

Mr. W. Johnson, DELCS-R-T
USAERADCOM
CS & TA Laboratory
Ft. Monmouth, NJ 07703

2) Sponsor Admin/Contractual Matters:

Mr. N. Attia, DRDEL-AQ-MB (ATT)
Ft. Monmouth Contracts Office
CS/FF Contracts Branch
USAERADCOM
Ft. Monmouth, NJ 07703

efense Priority Rating: DO-A7 Military Security Classification: None
(or) Company/Industrial Proprietary: ---

ESTRICTIONS

ee Attached --- Supplemental Information Sheet for Additional Requirements.

ravel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

quipment: Title vests with

OMMENTS:

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
FEB 1983
RECEIVED
Research Reports
Office

OPIES TO:

esearch Administrative Network	Research Security Services	Research Communications (2)
esearch Property Management	~~Reports Coordinator (OCA)~~	Project File
ccounting	GTRI	Other Echard
rocurement/EES Supply Services	Library	Other

ORM OCA 4:781 (Rev.982)

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

Date 5/4/83

Project Title: Airborne Test Bed Development Program

Project No: A-3468

Project Director: J. D. Echard

Sponsor: U. S. Army ERADCOM, Ft. Monmouth, NJ

Effective Termination Date: 4/20/83

Clearance of Accounting Charges: 4/20/83

Grant/Contract Closeout Actions Remaining:

- [x] Final Invoice ~~and Closing Documents~~
- [ ] Final Fiscal Report
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ______

Assigned to: RAIL-AD (~~School~~/Laboratory)

COPIES TO:

Administrative Coordinator	Research Security Services	EES Public Relations (2)
Research Property Management	Reports Coordinator (OCA)	Computer Input
Accounting	Legal Services (OCA)	Project File
Procurement/EES Supply Services	Library	Other Echard

FORM OCA 10:781

A-3468

Research and Development Technical Report

FINAL REPORT DAAK20–83–M–0208

CS & TA LABORATORY UTILIZATION OF HOWLS ADVANCED AIRBORNE RADAR

By
G. W. Ewell, R. D. Hayes, E. K. Reedy

Georgia Institute of Technology
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332

April 12, 1983

Prepared for

ERADCOM

US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

When this report is no longer needed, Department of the Army organizations will destroy it in accordance with the procedures given in AR 380-5. Navy and Air Force elements will destroy it in accordance with applicable directions. Department of Defense contractors will destroy the report according to the provisions of the Industrial Security Manual for Safeguarding Classified Information. All others will return the report to the controlling DA office.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER DAAK-20-83-M-0208	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CS&TA Laboratory Utilization of HOWLS Advanced Airborne Radar		5. TYPE OF REPORT & PERIOD COVERED A-3468 Final Technical Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G. W. Ewell, R. D. Hayes and E. K. Reedy		8. CONTRACT OR GRANT NUMBER(s) DAAK20-83-M-0208
9. PERFORMING ORGANIZATION NAME AND ADDRESS Georgie Institute of Technology Engineering Experiment Station Atlanta, GA 30332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Electronics Research & Development Command (DELCS-R-M) Ft. Monmouth, NJ 07703		12. REPORT DATE April 1983
		13. NUMBER OF PAGES 41
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office) Same as above		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to U.S. Government Agencies only. Test and evaluation April 1983. Other request for this document must be referred to U.S. Electronics Research & Development Command, (DELCS-R-M), Ft. Monmouth, NJ 07703

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

airborne radar
test bed
radar emulation
technology demonstration
moving and stationary target detection
remotely piloted vehicle (RPV)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The utilization of an advanced airborne radar by the U.S. Army Combat Surveillance and Target Acquisition Laboratory (CS&TAL) to emulate advanced radars and demonstrate advanced radar technology was assessed in terms of objectives and priority of utilization, hardware adequacy, personnel and organizational requirements, and potential support sources. The radar was developed for the Hostile Weapons Location System (HOWLS) by the Massachusetts Institute of Technology Lincoln Laboratory (MIT/LL) for the Defense Advanced
(continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. (continued)

Research Projects Agency (DARPA) and the U.S. Army. The HOWLS Advanced Airborne Radar is a coherent, K_u-band airborne radar with data link and ground-based van containing most of the data processing and recording equipment.

In the configuration expected to be delivered to the Army, the radar will support research and investigations on detection of ground movers. With perhaps only few hardware and software modifications, the radar could be configured to demonstrate the remotely piloted vehicle (RPV) radar in an air defense role. Significant growth of both the hardware and software, however, is necessary before the radar can support technology development and signal processing efforts currently being investigated for detection and classification of stationary ground targets. Resources required to support the radar include about 10 people for management and planning, airborne radar support, and ground van support.

The test bed radar can serve as a calibrated data collection system and allow emulation of techniques to be demonstrated in real battlefield type scenarios. The radar can be used in support of tests for programs such as E-SCAN, PRV, HAWFCARS, and FOPEN. The advantages of acquiring sensor data and cueing concepts for ground based systems such as DIVADS, AFCORS, SHORADS, and NURADS can be demonstrated with the airborne test bed radar. Highly calibrated data can be collected to provide better modeling and insight into the effectiveness of small projectiles, rockets, and missiles being developed for CAWS, MLRS, ASSAULT BREAKER, WAAM, and other munitions.

FINAL REPORT
GIT/EES PROJECT A-3468

CS&TA LABORATORY UTILIZATION OF HOWLS ADVANCED AIRBORNE RADAR

By
G. W. Ewell, R. D. Hayes, E. K. Reedy

Prepared for
U.S. Army Electronics Research & Development Command
Fort Monmouth, NJ 07703

Under
Contract DAAK20-83-M-0208

12 April 1983

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332

PREFACE

The report presents the findings and recommendations of a study conducted by the authors to consider operational utilization and management plans associated with the acquisition, by the U.S. Army Combat Surveillance and Target Acquisition Laboratory, of the HOWLS Advanced Airborne Radar developed by MIT/LL under sponsorship of the Defense Advanced Research Projects Agency and the U.S. Army. The opinions expressed herein are those of the authors and should not be construed as representing official U.S. Army position unless so indicated.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION 1

INTRODUCTION AND BACKGROUND

1.1 OVERVIEW

A short study was conducted by the authors of this report to consider both operational and management questions associated with the U.S. Army Combat Surveillance and Target Acquisition Laboratory (CS&TAL) acquiring, maintaining, and operating an experimental advanced airborne test-bed radar (originally called HOWLS) developed for the Defense Advanced Research Projects Agency (DARPA) and the U.S. Army by Massachusetts Institute of Technology Lincoln Laboratory (MIT/LL). This report presents the findings, conclusions, and recommendations resulting from that study.

1.2 PROBLEM

As outlined by the personnel of the CS&TAL, the primary purpose of the study was to address procedures, plans, and priorities associated with the Laboratory's acquiring, maintaining, and operating the MIT/LL-developed Advanced Airborne test-bed radar originally called HOWLS (Hostile Weapons Location System). Four specific areas of particular interest were also identified for detailed investigation and comments:

(1) Objectives and Priority of Utilization. In what area or areas should the initial investigations and experiments be conducted with the radar? Three candidate areas were identified: Air Defense, Ground Movers, and Ground Sitters. All of these areas assumed that the Airborne Radar would be configured to emulate a Remotely Piloted Vehicle (RPV) radar.

(2) Hardware Adequacy. What are the basic capabilities of the radar and does the radar hardware have sufficient inherent capabilities to conduct experiments and demonstrations in support of present CS&TAL thrusts in advanced signal processing, target detection, and target classification?

(3) Personnel and Organizational Requirements. What types and numbers of CS&TAL personnel will be required to support a "first class operation?" Also, augmentation support in the form of time and materials contracts will probably be required. Identify the potential augmentation required and also comment on an organization for managing radar operation.

(4) Potential Support Sources. Potential customers for support operation of the airborne test bed or sources of additional funding to support operation of the radar should be identified. The flexibility of the airborne test bed to emulate other airborne target acquisition and weapon delivery system targeting sensors will allow the test bed radar to support many other DOD as well as Army programs. Specifically, the radar could provide valuable early developmental data for HAWFCARS, SOTAS, E-SCAN, and, perhaps, PAVEMOVER.

1.3 HOWLS ADVANCED AIRBORNE RADAR

Tables 1, 2, 3, and 4 describe the general key system capabilities, functional modes, and principal parameters of the advanced airborne radar. The HOWLS Advanced Airborne Radar is a coherent, K_u-band airborne radar with data link and ground-based van containing most of the data processing and recording equipment. The present understanding is that the K_a-band noncoherent capability indicated in Table 1 will not be a part of the system so delivered to the Army. Also, the inertial navigation system (INS) is government furnished equipment (GFE) from the Air Force at Wright-Patterson AFB. Arrangements will have to be made to continue this GFE.

Not all of the functional modes are presently operational due to non-availability of the appropriate software to support all modes.

TABLE 1. ADVANDED AIRBORNE RADAR GENERAL CHARACTERISTICS

SYSTEM FEATURES	FUNCTIONAL MODES
o K_u-Band Coherent Radar	o Contextual Ground Map
o K_a-Band Noncoherent Capability	- Real Aperture
o Programmable Mode/Parameter Flexibility	- Doppler Beam Sharpening
	- Synthetic Aperture
o Pod Mounted Phased Array	o Fixed Target Detection
o Microprocessor Control	o Ground Moving Target Detection
o 12 MBS Data Link	o Doppler Spectral Signature
o Ground Based Processing	
o Inertial Navigation System	

TABLE 2. SUBUNIT SPECIFICATIONS

SUBUNIT	SPECIFICATIONS
Antenna	K_u-Band, 208 Elements
	Linear Phased Array
	0.5° Beamwidth
Transmitter	1500 W Peak, 30 W average
	-50 dBc Stability
Microwave	4 Coherent Frequencies
	64 Noncoherent Frequencies
	TWT Driver
Exciter	Linear FM Pulse Expansion, 2 μs, 50 MHz
	PRF 60 Hz to 40 kHz
	8.87 μs, 13 Bit Barker Phase Coded Pulse
Receiver	Linear FM Pulse Compression 30 ns
	Linear and Logarithmic Receiver
	I&Q and Amplitude Data
A/D Converter	8-Bit, 80 MHz
	Barker Pulse Compression & Equalizer:
	0.887 μs, > -30 Time Sidelobes
Airborne Radar Controller	8 Bit Microprocessor
	Mode and Parameter Control
	Beam Steering Computer
	Range Buffer: 840 Range Cells,
	80 MHz Sampling
Data Link	12 MBS, Downlink
	80 kBS, Uplink
	C-Band

TABLE 3. PRINCIPAL TECHNICAL SPECIFICATIONS

PARAMETER	SPECIFICATION
Transmitted Power	1500 W Peak (150 kW, EFF)
	30 W Average
Range Resolution	3 m Pulse Nominal
	5 m Pulse Compression (Linear FM)
	30 m Pulse Compression (13 Bit Barker Coded)
Azimuth Resolution	6 mrad, Real Aperture; < 2.5 mrad, DBS
Frequency	Stable References: 16.1, 16.2, 16.3, 16.4 GHz
	VCO: 84 Discrete, 16.0 to 16.5 GHz
PRF	80 Hz to 40 kHz
Pulse Lengths	CW Pulse 20 ns to 1800 ns
	PC 2 μs Trans/30 ns Comp
Range Samples	840 I,Q
System Bandwidths	2, 10, 15, 50 MHz
Mixer Preamplifier NF	5.5 to 8.5 dB
A/D Conversion	8 Bit, 80 MHz
Antenna:	
Main Array	2.5 m
DBS Array (Integral)	0.3125 m
Main Array Parameters:	
Elements	208
Gain	28.5
Sidelobes (Peak)	-20 dB
Scan Coverage	± 30°
Modes/Parameters	Processor Controlled
Data Link:	
Uplink	80 kBS
Downlink	12 MBS

TABLE 4. RADAR OPERATIONAL MODE/PARAMETER SUMMARY

PARAMETER	GROUND MAP	FIXED TARGET DETECTION	FIXED TARGET IDENTIFICATION	GROUND MTI	DOPPLER BEAM SHARPENING	SAR SPOTLIGHT
PRF (kHz)	4-11.25	4-11.25	4-40	4	4	3
PULSE RESOLUTION (m)	3-10	3-10	10	10	3-10	5
AZIMUTH RESOLUTION (mrad)	5	5	5	6	5 Unfocused 0.5-1 Focused	<0.1 (3 m)
TRANSMIT MODE	Noncoherent* Freq Agility	Noncoherent* Freq Agility	Coherent	Coherent	Coherent	Coherent
INDEPENDENT TRANSMIT SAMPLES	Up to 84	Up to 84	1	1	≥ 2	≥ 2
NO. CHANNELS	1	1	2	2	2	2
RANGE WINDOW (km)	>1	1.4	0.1-1	>1	>1	0.5 Range 0.5 Azimuth
OPERATING RANGE (km)	1-25	1-5	1-2.5	1-15	1-25	5-20
MIN DETECTABLE VELOCITY (m/s)	-	-	-	0.5-1.5	-	-
BLIND VELOCITY (m/s)	-	-	-	31.2	-	-

* Frequency may be shifted at 4kHz rate (once every 256 microseconds)

SECTION 2
PRIORITIES AND OBJECTIVES

2.1 INTRODUCTION

In addition to the operational demonstrations or emulations of an advanced RPV radar operating in an air defense, ground mover detection and ground sitter detection mode or modes, it also seemed appropriate to consider the advanced airborne radar as a potential test bed to demonstrate and evaluate certain advanced radar technology capabilities such as RPV radar MTI, stationary target detection, synthetic aperture radar from an RPV, etc.

2.2 OPERATIONAL

The advanced airborne radar will be reconfigured to be more representative of an RPV based radar primarily by replacing the present antenna with a smaller mechanically scanned antenna having an aperture of approximately 18 x 6 inches. This antenna would be mechanically rotated over 360 degrees in azimuth. The antenna size was chosen to conform to form and fit restrictions imposed by the RPV platform.

To a large extent, the radar priorities and demonstration objectives will be dictated by overall Army priorities, equipment needs and the potential interface of an RPV radar platform with major Army programs such as HAWFCARS, SOTAS, E-SCAN, etc. The limited information available to the study team coupled with the evolutionary, changing nature of requirements in this area, makes the prioritization of radar usage difficult.

However, other factors which are somewhat easier to assess also influence utilization priorities and objectives. For example, short term utilization will probably be based on the present capabilities of the equipment and the hardware/software configuration. Future utilization will depend on growth potential of the hardware and software and the resources available to support the system. Obviously, a direct connection should exist between resources available, overall Army needs, and the perceived benefit of this radar to ongoing Army research and major program objectives.

In the configuration that is expected to be delivered to the Army, the radar will support research and investigations on detection of ground movers. Because of limited resources available and the large amount of effort and training required to accomplish the change-over from MIT/LL to Army management, coupled with the need to quickly gain visibility within the community and advertise the availability of the equipment for supporting other programs, first priority should be placed on demonstrating an RPV radar operating against ground movers. Efforts in this area would represent a continuation of some of the major research conducted by MIT/LL in detection of ground movers, albeit with a reconfigured airborne radar to emulate the RPV scenario.

The need to utilize the present equipment configuration and capabilities with minimal modification, coupled with a desire to quickly realize a return from the airborne test bed are primary criteria for establishing utilization priorities. Thus, a next logical area to demonstrate an RPV radar's capabilities would be in an early warning air defense role in support of Army SHORADS/C^2 requirements. With perhaps only minor modifications to system software to change such things as radar scan rates, waveforms, etc., and, hopefully, little or no modification to hardware, the radar could be configurated to demonstrate the RPV radar in such an air defense role.

The utilization priorities discussed above have been established primarily on the basis of anticipated resources and a lowest risk changeover and schedule. Unfortunately, establishment of a priority in this manner may not accurately reflect the changing Army needs and may possibly result in utilization of the equipment to investigate problems and applications which are not most important to the Army.

One of the most challenging and difficult operational problems currently facing the Army R&D community is the detection and classification of stationary ground targets in a high clutter background (S/C $\leq$ perhaps 0 dB). Certainly the airborne RPV radar has significant capabilities to provide valuable information to attack this problem. However, significant growth of both the hardware and software must take place before the radar can support the technology development and signal processing efforts currently under investigation by the Army. The algorithms for stationary target detection and classification typically require more complete measurement of the target signature (i.e., in polarization and amplitude or high resolution) than the radar can presently support. Thus, to support programs in the detection of ground sitters will require significant hardware and software modifications. Primarily for this reason, detection of ground movers is given third priority in comparison with the previous two operational objectives.

A very strong caveat must be placed on these recommendations, however. Remember that the priority was established primarily on the basis of present (or easily upgraded) equipment configuration and the assumption of limited resources. Overall Army priorities, major program requirements, or the availability of significantly more resources (funding and people) could alter these priorities. Also, to some extent, the three operational areas could be investigated in a coordinated and somewhat overlapping fashion, even with limited resources, by following a schedule similar to that shown in Figure 1.

The schedule of events depicted in Figure 1 emphasizes a potential problem. To proceed on the schedule shown, requires several simultaneous software development efforts. Even under the most favorable circumstances, this would cause considerable concern, but in a radar system completely controlled and dominated by software which has only marginal documentation, the probability of accomplishing the tasks as outlined is very small unless a major software development and, perhaps, documentation effort is undertaken. As a point of record, the study team believes the advanced airborne radar hardware to be only "the tip of the iceberg" in the overall system. Thus, considerable care should be taken in the MIT/LL to Army transition process to ensure that Army personnel gain as complete an understanding as possible of the software system at an early point in the transition process.

2.3 TECHNOLOGY DEMONSTRATIONS

In consonance with the investigation of operational applications of an RPV radar should be the investigation of certain technology questions. Such an approach is implied in Figure 1. The technology investigation can conveniently be divided into three categories by time frame as shown in Table 5. These time frames generally correspond to the operational demonstrations. The rationale for grouping the technology demonstrations as shown in Table 5 is very similar to that used in arriving at the recommended timing

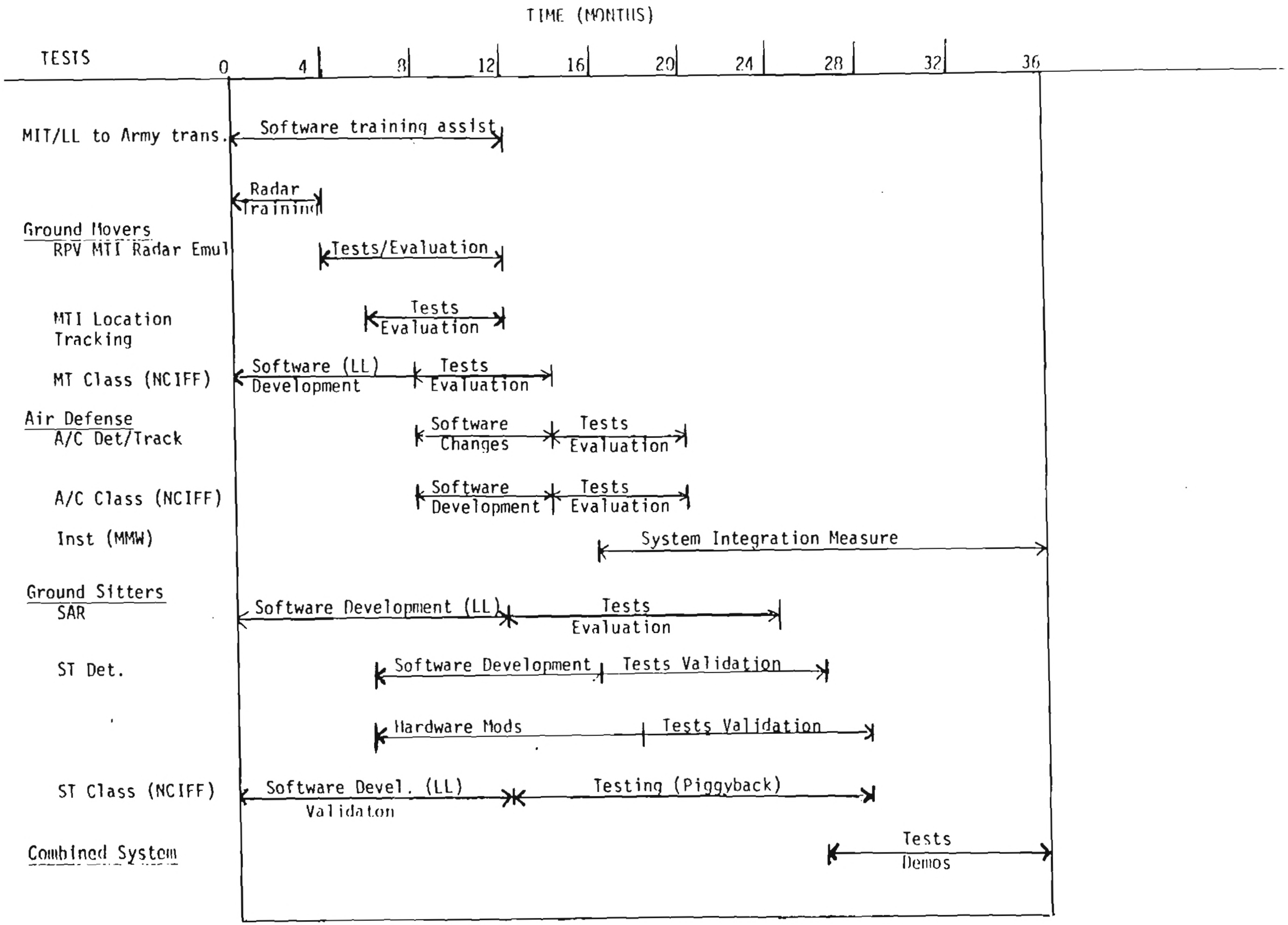

Figure 1. RPV radar demonstration schedule.

TABLE 5. TECHNOLOGY DEMONSTRATIONS

- o Short Term Demonstrations (0 to 14 months)
  - -- MTI from an RPV platform - measurements and evaluation
  - -- Moving target location and tracking
  - -- Moving target classification (NCIFF)

- o Intermediate Term Demonstrations (8 to 36 months)
  - -- Aircraft Detection and tracking
  - -- Aircraft Classification (NCIFF)
    - * JEM
    - * Rotor modulation
    - * High resolution
    - -- Instrumentation/reflectivity (Dual mode with MMW radar)

- o Long Term Demonstrations (6 to 36 months)
  - -- SAR (DBS, Spotlight)
  - -- Stationary target detection
  - -- Stationary target classification (NCIFF)
  - -- ISAR
  - -- Vertical resolution

for the operational demonstrations shown in Figure 1; that is, depending strongly on anticipated available resources and a relatively low risk approach.

Some key technical questions will need to be addressed in each one of the technology categories. Several, but certainly not all, of these questions are identified in Tables 6, 7, and 8. The key technical issues identified in these tables span over operational, hardware and software, and data gathering areas and represent only a partial list.

There are many tests which need to be conducted before final design of the RPV radar. Let us consider just the detection of moving airborne targets.

There are two basic types of aircraft to be detected in the combat region of concern to the RPV mounted sensor. Those aircraft which are in the air space below 3 km consist of slow movers (60 knots) and high speed (600 knots) attack units. Although different radar transmitted waveforms may be required to produce optimum detection of moving targets, the requirements of clutter reduction and adequate signal-to-interference ratios are needed regardless of target speeds. The various radar parameters which affect the signal-to-interference in a pulse Doppler radar include pulse repetition frequency, antenna scan rate, pulse length, antenna beamwidth, aircraft (sensor platforms) speed and target speed.

The prime advantage of pulse Doppler radars in the detection of moving targets is the reduction of fixed target returns and reduction of clutter returns. A typical distribution of targets in the Doppler domain is shown in Figure 2. Two approaches are classically employed: (1) a low PRF system which has unambiguous range resolution but suffers from a low number of hits on the target and ambiguous Doppler resolution sampling for target velocity determination and (2) high PRF systems which produce highly ambiguous range information to the extent that the spatial location of the target is unknown but will provide many hits on the target and sampling can be made at a sufficient rate to provide Doppler resolution for determination of target speed.

The test bed radar being provided from the present HOWLS program has a variable PRF, up to 40 kHz, so that tests and demonstrations can be made to show advantages, disadvantages, and the preferred waveform for detecting and

TABLE 6. KEY TECHNICAL ISSUES FOR SHORT TERM DEMONSTRATIONS (PRIMARILY MOVING TARGET)

- RPV optimum MTI configuration and implementation
- Design data for RPV radar
- Coherent versus non-coherent versus coherent-on-receive
- Separation of signal processing between on-board and ground
- MTI radar implementation with fixed bandwidth data link
- Platform motion and moving clutter spectral spreads on moving target classification algorithms
- Data rates and waveforms for moving target location and tracking

TABLE 7. KEY TECHNICAL ISSUES FOR INTERMEDIATE TERM DEMONSTRATIONS (PRIMARILY AIR DEFENSE)

- Data rates, waveforms, and detection profiles for aircraft detection/tracking
- Interface of RPV information with other command/control elements (C^2)
- Coherency questions addressed in short term, except for aircraft detection
- Combined MMW/K_u-band sensor package and effectiveness

TABLE 8. KEY TECHNICAL ISSUES FOR LONG TERM DEMONSTRATIONS
(PRIMARILY GROUND SITTERS)

- o RPV SAR FEASIBILITY
  - -- Implementation (DBS, Spotlight, SAR)
  - -- Real Time Processing
  - -- Processing Split Between Platform and Ground
  - -- Data Link Requirements
  - -- Platform Stability
  - -- Radar Parameters (Waveform, Antenna, etc.)
  - -- Software Availability
- o STATIONARY TARGET DETECTION
  - -- Implementation (SPR, PCD, ADV CFAR, Frequency Agility, etc.)
  - -- Resolution Requirements
  - -- Dual Polarization Antenna
  - -- Signal Processing Split
  - -- Data Link Requirements
  - -- Target Viewing Angle Effects
  - -- Clutter
- o STATIONARY TARGET CLASSIFICATION (NCIFF)
  - -- Implementation (HRR, Polarization & Frequency Agility, etc.)
  - -- Resolution Requirements
  - -- Vibrational Signatures and Capability
  - -- Target Depression Angle Effects
  - -- Clutter
- o ISAR (MOVING TARGETS)

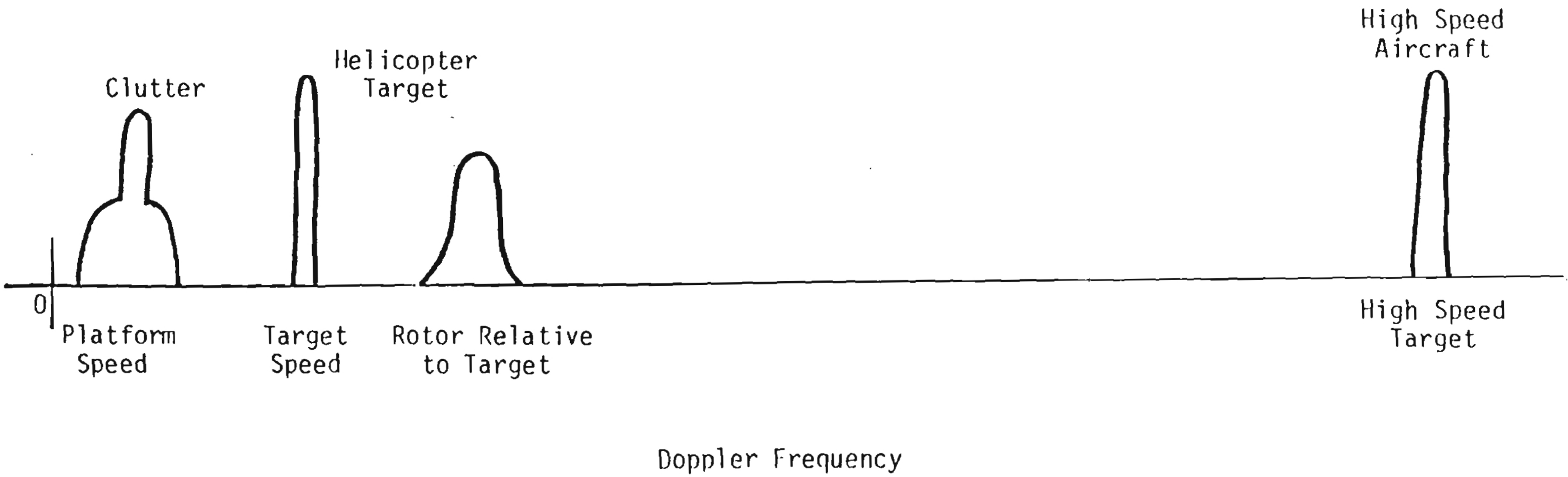

Figure 2. Relative Doppler frequencies from moving platform.

tracking both slow and fast moving airborne vehicles and ground based moving targets. The bandwidth of the Doppler signal processor is the same as the PRF. The frequency resolution within this bandwidth depends on the technique employed. For example, if fixed bandpass filters are employed, then the resolution is controlled by the filters, and the narrower each filter then the more filters required to detect across the total required bandwidth of observation. If Fourier transforms are employed, then the resolution in frequency is the PRF divided by the number of sampling points in the FFT. To decrease the effect of noise and enhance the signal level, then it is necessary to increase the number of sample points in the FFT or decrease the bandwidth of the discrete filters. There is one FFT sample point for each transmitted pulse; thus, if it is required to process in a short period of time, a high PRF must be generated. It is possible to obtain high resolution (large FFT) over a wide frequency range (large PRF), to detect fast and slow moving targets and to reduce the effects of clutter, noise and other interference, but it is not possible to know where the target is located in range at the high PRF, without additional, special waveform control.

There are several important areas which are not addressed as either short or intermediate term programs which are an important part of the laboratory technical mission, and these will be addressed in the long term programs. The reasons for deferring these programs varies, and includes such considerations as availability of equipment, required upgrades to the radar equipment, or identification of effective technical approaches for achieving desired performance.

One of the more visible of these long term demonstrations will be those designed to shed light on the Stationary Target Identification/Indication (STI) problem. Techniques which are currently being considered for STI include advanced CFAR techniques, high range and azimuth resolution, polarization processing, and high resolution Doppler analysis. However, specific techniques or combinations of techniques which will be effective in demonstrating STI are not entirely clear.

The natural extension of STI is to non-cooperative IFF or positive target identification. This leads naturally to consideration of simultaneous employment of different sensors such as millimeter-wave radar, FLIR, or video sensors to improve target ID for long-term demonstrations. Higher azimuth resolution techniques such as synthetic aperture radar (both spotlight and side-looking) may be employed for such demonstration. Other techniques such as polarization processing and high range resolution may be desirable.

The airborne test bed may also form the basis for a FOPEN demonstration. Such a demonstration could employ existing receivers from the IF back including data link and ground equipment, in connection with a different, lower frequency, RF section. Such a major modification, however, is definitely a demonstration requiring considerable planning and support.

SECTION 3
HARDWARE ADEQUACY

3.1 INTRODUCTION

Questions of hardware adequacy are considered to include system software also. In particular, the software will probably be the driver in many of the test programs conducted with the RPV version of the advanced airborne radar. According to MIT/LL personnel, the advanced airborne radar uses three basic computers each having its own language, software, and hardware. Some indication of the amount of software is given in Table 9. Little complete documentation of the software presently exists. However, a clear indication of the level of software documentation required to accomplish a smooth transfer is not available.

TABLE 9. ADVANCED AIRBORNE RADAR SIGNAL PROCESSORS/COMPUTERS

o	MODCOMP COMPUTER		
	Languages:	Fortran	- 5200 lines of source
	(Real Time)	LFP	- 5500 lines of source
		Assembly	- 6000 lines of source
o	WESTINGHOUSE PROGRAMMABLE SIGNAL PROCESSOR		
	Languages:	JOVIAL	- 5500 lines of source
		Assembly	- 2000 to 3000 lines of source (est)
	Memory	500,000 words	
o	GE MICROPROCESSOR (ON AIRCRAFT)		
	Language:	Assembly	

It should be emphasized that the software for this system resides in several computers and is rather complex. Becoming proficient in maintenance and modification of this software is a non-trivial task and will necessitate considerable training, even for experienced, dedicated, competent programmers. Estimates for the amount of time for each programmer to become familiar with his task ranges from six months (probably optimistic) to nine months (probably also optimistic). Plans for the test bed should provide for the necessary training period to permit efficient operation and modification of the operating software.

Evidently, the hardware, especially the airborne hardware, has been relatively reliable. (MIT/LL personnel also state that they have been "lucky," and emphasize the value of the full time engineer supplied by General Electric to maintain the airborne part of the system.) As with the software, however, only limited system documentation presently exists, although some is evidently being developed at the present time. Recent changes have not been included in available drawings and documentation.

Note that the INS is not a part of the package to be transferred. This equipment is GFE to MIT/LL from the Air Force at Wright-Patterson Air Force Base.

The capability of the hardware/software combination to support both the operational and technology demonstrations outlined in Section 2 is critically dependent on certain key radar parameters such as scan rates, waveforms, polarizations, coherency, bandwidth, pulse compression, frequency agility, data link capabilities, data recording, and processing software. The overall capability of the system to support the specific areas of interest are discussed in the following paragraphs.

3.2 MOVING TARGETS

Most of the research efforts conducted with the radar in the fixed wing aircraft configuration addressed detection of ground movers (and sitters) in a clutter environment. Thus, the basic capability for continuing to address this problem in an RPV radar configuration currently exists within the hardware and software. However, since a mechanically scanning antenna, continuously scanned in azimuth, will be employed to emulate an RPV radar, certain software changes to handle the different scan rates, perhaps waveforms, and coverage area will be necessary. Also, a valuable extension of the demonstrations might be accomplished by providing a software simulation of the platform motion characteristics of a RPV to make the data more realistic.

For the moving target NCIFF problem, software changes will be necessary to incorporate specific spectral analysis (including vibrational signatures) and target identification algorithms. Different MTI implementations can probably be simulated with the existing hardware (i.e., fully coherent, coherent on receive, and non-coherent or clutter referenced).

3.3 STATIONARY TARGET TECHNOLOGY

As previously indicated, detection and classification of stationary military targets is considered to be an extremely high priority problem for all branches of the U.S. Armed Forces. The Army certainly considers this problem important as evidenced by the number of technology development efforts currently ongoing within several Army laboratories. The current leader in this effort is CSTA Laboratory.

An RPV configured version of the advanced airborne radar would represent a very valuable research tool to support the continuing research being conducted in this area by CS&TAL.

The stationary target discrimination/classification problem is considerably more difficult than the moving target problem since a Doppler-shifted signature is not available to assist in separating targets of interest from clutter in the same cell or contiguous cells, especially in situations where the surrounding clutter may be much larger in amplitude than the stationary target of interest. In most cases, clutter is non-homogenous, which significantly reduces the effectiveness of adaptive thresholding CFAR techniques. Thus, other approaches must be investigated.

Most of the recent efforts in the stationary target (fixed targets and nonmoving mobile targets) discrimination area have concentrated on exploiting target signature characteristics in the amplitude, frequency, and polarization domains. Not one of these approaches, operating alone, has provided a complete solution. Using several sources of data, various implementations of specific combined processors have been investigated.

Most of the current effort in automatic stationary target recognition for real aperture radar applications involves the examination of target range profiles using both classical and recently emerging pattern recognition technology and statistical testing theory. Several degrees of freedom can be applied to the range profiles (time, frequency, polarization, aspect angle, or multiple looks). Various combinations of these signature profiles seem to provide the most promising results.

Present and future efforts in the classification area are focused on investigating the robustness of the various classification algorithms to target effects (rotation, type, etc.) clutter background, preprocessing, and alien targets and to the development and evaluation of a working 5-class target recognition algorithm, using measured data on real targets in both benign and clutter backgrounds.

In the CS&TA Lab program, these efforts are generally directed toward demonstration of a practical target discrimination and classification processor operating in the airborne test-bed radar. To properly support these investigations, the airborne test bed radar hardware and software must include certain required technical performance characteristics. These features and their present status are indicated in Table 10.

Most of the advanced stationary target discrimination processors under investigation by several organizations make use of polarization information, usually two orthogonal polarizations and more recently the complete polarization scattering matrix. As presently configured and in the planned RPV radar configuration, dual polarization measurement will not be possible and therefore such processors as SPR and PCD and their extensions and modifications cannot be tested and evaluated. Discrimination and classification algorithms based on advanced CFAR (typically amplitude-only processors) and frequency agility or multiple frequency measurements can be implemented and tested.

Stationary target classification makes use of as much target signature information as is available. Also, most of the more promising techniques depend on high resolution signatures in the range dimension for real aperture radars and both the range and angle dimension for synthetic aperture systems. The present radar hardware configuration has a 3 meter minimum range

TABLE 10. RPV RADAR STATIONARY TARGET PROCESSING CHARACTERISTICS

PARAMETER	PRESENT STATUS	STATUS REQUIRED FOR STI/C
System Resolution:		
Range	3 m/5 m/30 m	Not sufficient; more compression (< 1 m) required
Azimuth		
Real Aperture (RPV)	54 mrad	Not sufficient; desire < 1 m
DBS	Not available	
Spotlight	Not available	
Polarization	Single Linear	Dual required (new antenna)
Frequency	4 Coherent (16.1, 16.2, 16.3, 16.4) 64 Noncoherent	Probably sufficient
Data Link	12 MBS (down)	Depends on processor implementation
Radar Bandwidth	2, 10, 15, 50 MHz	Need > 150 MHz to support < 1 m resolution
Signal Processor	PFS/MODCOMP	Probably sufficient

resolution which will not allow sufficiently detailed target signature resolution for range-only classification. In addition, software to support the SAR mode is not complete. Polarization and frequency information are also used extensively for automatic target classification. The radar seems to have excellent frequency agility characteristics and would support classification and discrimination algorithms based on this phenomenon. As indicated above, the radar has only a single polarization capability. Dual polarization must be added to fully support the complete spectrum of classification and discrimination approaches under investigation.

A cursory investigation indicates that certain other ancillary features of the radar and associated system, including the data link, system bandwidth, radar waveform, and signal processing and computational equipment probably have the necessary flexibility to support a stationary target detection and classification research program.

3.4 SYNTHETIC APERTURE PROCESSING

3.4.1 INTRODUCTION

Resolution higher than currently available from the system may be necessary to provide additional detail concerning the details of potential targets. One means to achieve increased cross-range resolution is by use of so-called Synthetic Aperture Radar (SAR). There are a number of different synthetic aperture techniques which utilize the same basic principle, but have historically been termed Doppler Beam Sharpening (DBS), Strip SAR, and Spotlight SAR. Each of these approaches has its own unique set of requirements and imposes different sets of requirements on the radar system.

3.4.2 DOPPLER BEAM SHARPENING (DBS)

DBS is perhaps the most straightforward of the SAR techniques; it employs the different Doppler shifts of targets within the illuminated beam to generate increased cross-range resolution. The geometrical situation is illustrated in Figure 3 showing the location of scatterers within the beam and the resulting Doppler shifts associated with each scatterer: the difference in angular separation produces different Doppler shifts due to aircraft motion which provides increased cross-range resolution.

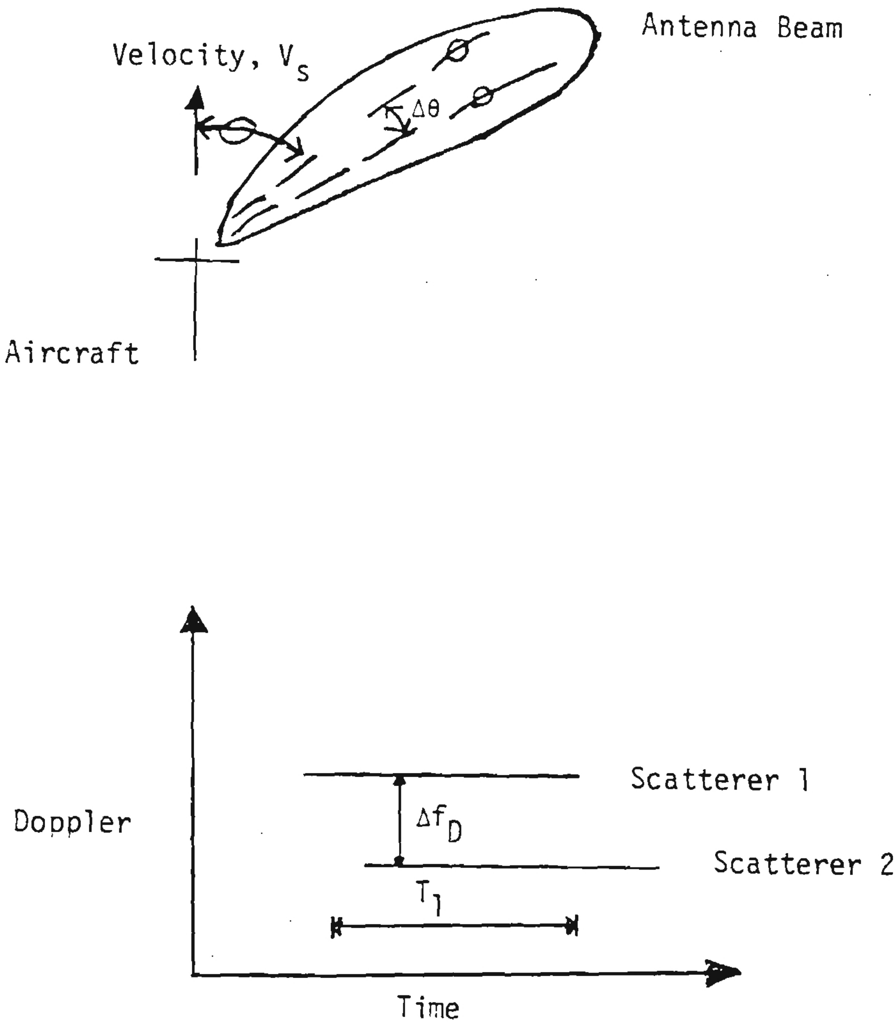

Figure 3. Geometrical and Doppler relationships for returns from targets which have angular separation when viewed by a moving radar system.

The difference in Doppler velocities for two stationary scatterers due to platform motion is

$$\Delta f_D = \frac{-2V_s \sin\theta \, \Delta\theta}{\lambda} , \tag{1}$$

where: Δf_D = difference in Doppler frequency of scatterers

V_s = platform velocity

θ = angle of scatterer from aircraft track

$\Delta\theta$ = angular separation of scatterers.

Since the Doppler filter resolution is inversely related to the integration time T_1, one may then determine

$$\Delta\theta = \frac{1.35\lambda}{2T_1 V_s \sin\theta} , \tag{2}$$

or the cross range linear resolution, r_θ is

$$r_\theta = \frac{1.35\lambda R_s}{2T_1 V_s \sin\theta} , \tag{3}$$

where R_s is the range to the scatterers.

Equation (3) sets limits on the frequency stability of the system, i.e., the frequency stability must be less than Δf_D over the integration period T_1. Consider a 3^o beam scanning at 10 rpm with 30 meter range resolution at a frequency of 16 GHz (λ = 1.9 cm) from a platform moving at 140 km/hr (38.9 m/s). The targets will remain within a range cell for approximately one second; this would actually permit a

$$\Delta\theta = \frac{(1.35)(1.9 \times 10^{-2})}{2(1)(38.9)(\sin 45^o)} = 4.66 \times 10^{-4} \text{rad} = 0.5 \text{ mils}, \tag{4}$$

however, this would require a frequency stability on the order of 0.1 Hz over a one second interval. More reasonable stabilities might be one part in 10^{10} which would give resolutions on the order of ten times this or $\Delta\theta \approx 5$ mils.

If the antenna is scanning and DBS is desired, there is an additional limit, i.e., the scan rate is about 60^o/s, so the beam dwells on each area only about 1/20 s, which further reduces the resolution to $\Delta\theta \approx 10$ mils.

Compensation for known linear motion is required to achieve maximum utilization and resolution; this may be accomplished either in hardware or software, but requires a knowledge of aircraft velocity.

The cross-range linear resolution for 5-10 mil DBS cross-range resolution is 50-100 meters at 10 km ranges. This is commensurate with the 30 meter range resolution, so additional range resolution would probably not be useful or desirable.

In summary, the DBS approach would:

- o Provide angular resolutions of from 5-10 mils
- o Be limited by beam dwell time (scanning) or frequency stability (non-scanning)
- o Require a knowledge of platform velocity
- o Provide cross-range resolution comparable with existing range resolution.

The software requirements for the DBS processing are currently being developed for the electronically scanned antenna, and it is expected that straightforward modifications will be required for the mechanically scanning antenna of the test bed.

3.4.3 STRIP SAR

The strip SAR uses the same basic approach as the DBS, i.e., use of Doppler signals which differ in frequency due to angular location to obtain increased angular resolution. A number of texts show that a focused system (which requires a knowledge of aircraft velocity) provides a cross-range resolution of

$$L/2,$$

where L is the aperture length. Thus, the maximum achievable cross range resolution for an 18 inch width antenna is 9 inches, but the target Doppler must be processed during the entire time it is within the 3° beam to achieve this resolution. For a platform moving at 140 km/hr (38.9 m/s), a 3^o, beam, and a target at 10 km, the processing time is

$$\frac{(3^o/57)(10^4)}{38.9} = 13.53 \text{ seconds.} \qquad (5)$$

Achievement of this full resolution would require a frequency stability which would permit Doppler resolution of 1/13 s. This implies a frequency stability which may be difficult to achieve. In addition, random platform motion may further limit Doppler resolution of the system.

The ultimate cross range resolution is not comparable with the existing range resolution of 30 meters. An increase in range resolution should accompany any implementation of strip SAR processing.

In summary, for strip SAR processing

- Cross-range resolution could be as high as 9 inches
- The beam must be pointed at 90° to the platform track
- Cross-range resolution may be limited by system stability
- Increased range resolution is desirable to fully utilize the SAR benefits
- A knowledge of platform velocity is necessary for aperture focusing
- Effects of random platform motion may become important
- Suitable software must be developed for SAR processing.

3.4.4 SPOTLIGHT SAR

Recent developments in SAR technology have resulted in the "spotlight" SAR which illuminates a single area on the ground and, due to increased dwell time, avoids the connection between cross-range resolution and aperture size. Currently, cross range resolutions of six inches are being demonstrated. The basic physical mechanism is the same as all of the SAR techniques, but the long dwell time permits large values of T_1 in Equation (2).

Again, the frequency stability of the system will probably be a limiting factor in such a system. In addition, the beam must be moved to maintain illumination of the same spot on the earth surface as the aircraft flies by. A precise knowledge of the aircraft velocity is again required in the signal processing scheme.

Processing images from a spotlight SAR is somewhat more complex than with the older SAR systems. At the present time, considerable manual manipulation is required to obtain acceptable images, and extensive software development may be necessary to achieve acceptable image quality in an automated system.

Since considerable cross-range resolution is achievable in the spotlight SAR, increases in system range resolution will be desirable for commensurate resolutions in the two orthogonal directions.

In summary, for the spotlight SAR

- o The beam must be pointed at a single spot while the aircraft flies by
- o Cross-range resolution can be independent of aperture size (6" typical achieved)
- o Doppler stability and resolution must be high
- o Software development may be a long and difficult task
- o Increases in range resolution are desirable for comparable resolutions in range and azimuth

3.5 TRACKING/MEASUREMENTS

The ability of an RPV to detect and locate ground movers and low flying aircraft can be demonstrated by using a scanning antenna mounted on the underside of a helicopter. The antenna used with the AN/TRQ-33 search system can be modified easily to perform airborne tests and provide meaningful results. The antenna is approximately 18" x 6" in size and is shaped in elevation (6") to produce a cosecant squared far-field pattern. The far-field pattern is approximately 3 degrees in azimuth and is shaped from 30 degrees to 5 degrees in elevation. When the antenna is flown at a 3 km altitude, the far-field pattern will provide illumination on the ground from 35 km to 5 km such that a given size target will produce a constant amplitude return.

Now consider the following system parameters of a pulse Doppler radar. A PRF of 4 kHz will provide unambiguous range detection past 35 km range. With a 128 point FFT, a single-look across the frequency band of 4 kHz can be made in 32 milliseconds. This corresponds to Doppler speeds from near zero to 37 m/s (84 miles/hr). When the helicopter platform containing the radar is moving at 30 m/s, then the beam on the ground will move almost 1 meter during the 32 millisecond analysis time. Typically 4 or 5 observations of a given area are made to ensure adequate signal level and thus provide target detection. This observation (or integration) time limits the spatial resolution to a minimum of 5 meters and thus a minimum pulse length of 33 nanoseconds.

With the antenna scanning a 360 degree azimuth sector at the rate of 10 RPM, then the update or revisit time is 6 seconds. Thus, if the sensor is moving at 30 m/s, the footprint on the ground will move about 36 range cells directly along the flight path for each antenna scan. If detection cannot be made on a single scan, then provisions must be made to keep track of the ground positions on a scan-to-scan basis. With the 3 degree azimuth beamwidth, the cell of resolution broadside to the platform will move about 20% (at 10 km range) of the beamwidth in a single scan, thus registration from several scans will be reasonably simple. Of course, the fractional change in beamwidth is even less at further ranges (10% at 35 km).

These system values all provide reasonable parameters for the detection of slow moving airborne targets and for ground moving targets. Now consider a high speed aircraft moving through the surveillance area under the RPV. A 600 knot aircraft will pass through the 70 km range in less than 4 minutes. At the 4 kHz PRF and 5 meter range resolution, there will be only about 6 pulses on the high speed target in one range cell of observation. This will not be adequate for Doppler resolution or target detection. Thus, it will be necessary to change the format of the transmitted signal. A PRF of 40 kHz will provide 67 pulses in a range cell; a 16 point FFT would then allow 4 "looks" to be made in one cell of resolution. This should be adequate for detection on a simple scan. At the scan rate of 60 degrees/second, then there would be a maximum of 40 observations of the high speed aircraft as it passed through the 70 km circle under surveillance. If the high speed aircraft being detected moves along a radial path to the RPV, then the high PRF of 40 kHz will not allow the range to the target to be determined. If the target moves in a path such that different azimuth cells are crossed, however, the location route can be determined from a time sequence of azimuth locations relative to the RPV platforms.

These suggested parameters are all well within the operational limits of present day devices. Thus an airborne test bed can be assembled from existing equipment and demonstrations can be made.

There are several items which are not known with sufficient accuracy to make exact calculations and absolute predictions of system performance. Before final design of an operational system is completed, both the absolute magnitude and the frequency content in the Doppler domain should be measured for the targets to be detected and the various types of rain and ground clutter expected to be encountered. There are data on spectral content of wind blown trees measured with non-coherent radars. It would be wise to extend the data base by undertaking a measurement program to determine the spectral content when employing a coherent transmitted signal and to measure the effects on the clutter Doppler spectrum when using a spread spectrum and a frequency agile transmitted waveform. It is expected that the Doppler spread from ground clutter will be reduced using these waveforms, but it is not presently known how much change will occur from coherent transmission, spread spectrum, or frequency hopping transmission. Similar statements can be made regarding the radar backscatter from rain. Existing data from rain indicate that the spectral spread is an order of magnitude wider than that obtained from wind blown trees. The phenomenon of vertical shear causing wide spectral interference from rain has been observed in ground based radars. A well calibrated measurement program is needed to better define the effects from an RPV type platform and to evaluate the impact of coherent and frequency agile transmitted waveforms.

When making measurements or observations of phenomenological effects of events occurring in nature or from man-made objects, the measurement of the electrical properties has been more precise than the physical properties of the event. Many examples exist where descriptions of the medium, ground truth, surface coverage, material thickness, particle size, surface roughness, density, composition of non-homogenous materials, object motion and the like were inadequate. Examples are noted that the monostatic backscatter from rain will vary 10 dB as a function of raindrop size distribution as well as the total amount of water in the cell of resolution (rain rate). When measuring attenuation of signals through trees, the value of dB/meters will vary 100% to 200%, depending on the condition and type of foliage for every meter of penetration, not simply the outer dimensions of the tree. Thus, it is essential that proper measurements be made so that the objects under investigation can be adequately characterized.

With a limited size antenna, a beamwidth of about 3 degrees in azimuth will be generated from the AN/TRQ-33 system. At the desired detection ranges, a wide section of space will be illuminated in the azimuth plane. For the suggested configuration of locating the RPV at 3 km altitude and searching out to 35 km range, then the cross-range width on the ground will be about 1800 meters at maximum range, this is shown in Figure 4. Many targets will be located in 1800 meters, but the radars will report only one signal regardless of how many tanks, buildings, tents, or whatever are located in this cell of resolution. In addition to the low resolution and inability to identify separate targets in the cell, the location of the targets cannot be made much closer than about half the azimuth cell of resolution. Thus, if only one target is in the 1800 meter cell, the location of that target is known to within 900 meters. This is an order of magnitude too large for the users of the data.

There are a number of electronic techniques available to enhance the pointing accuracy and decrease the error in location. Such techniques as monopulse, synthetic aperture, Doppler beam sharpening, and beam splitting are employed for this improved pointing accuracy.

Let us consider the use of two radar sensors located such that the scanning beams are at 90 degrees to each other, as shown in Figure 5. Of course, one sensor could be deployed if enough time is allowed to move the sensor between locations. With the suggested 5 meter range resolution of the pulse Doppler radar, the two beams at 90 degrees will generate a 5 m x 5 m cell in space. This is fine grain resolution for surveillance operations. Consider the use of the AN/TRQ-33 antenna on an RPV at 3 km altitude. When the two RPVs fly paths separated by 20 km and displaced in range by 20 km, then a strip 20 km wide can be investigated in great detail.

Due to the altitude, the look down angle at 20 km ground range is 8.53 degrees, leading to a footprint on the ground of 5.06 meters. Thus at the intersection of the two 90 degree beams, the cell of resolution is 5.06 x 5.06 meters. However, when scanning off 10 km either side of the flight path (an angle of 26.6°), the cell is still small. From the geometry involved, the cell of resolution on the ground is 5.22 x 5.64 meters. Thus, over a 20 km strip on the ground, objects as small as a vehicle can be isolated.

If only one RPV is available and the two flight paths are flown in time sequence, then it will be required to have two known targets as a fixed

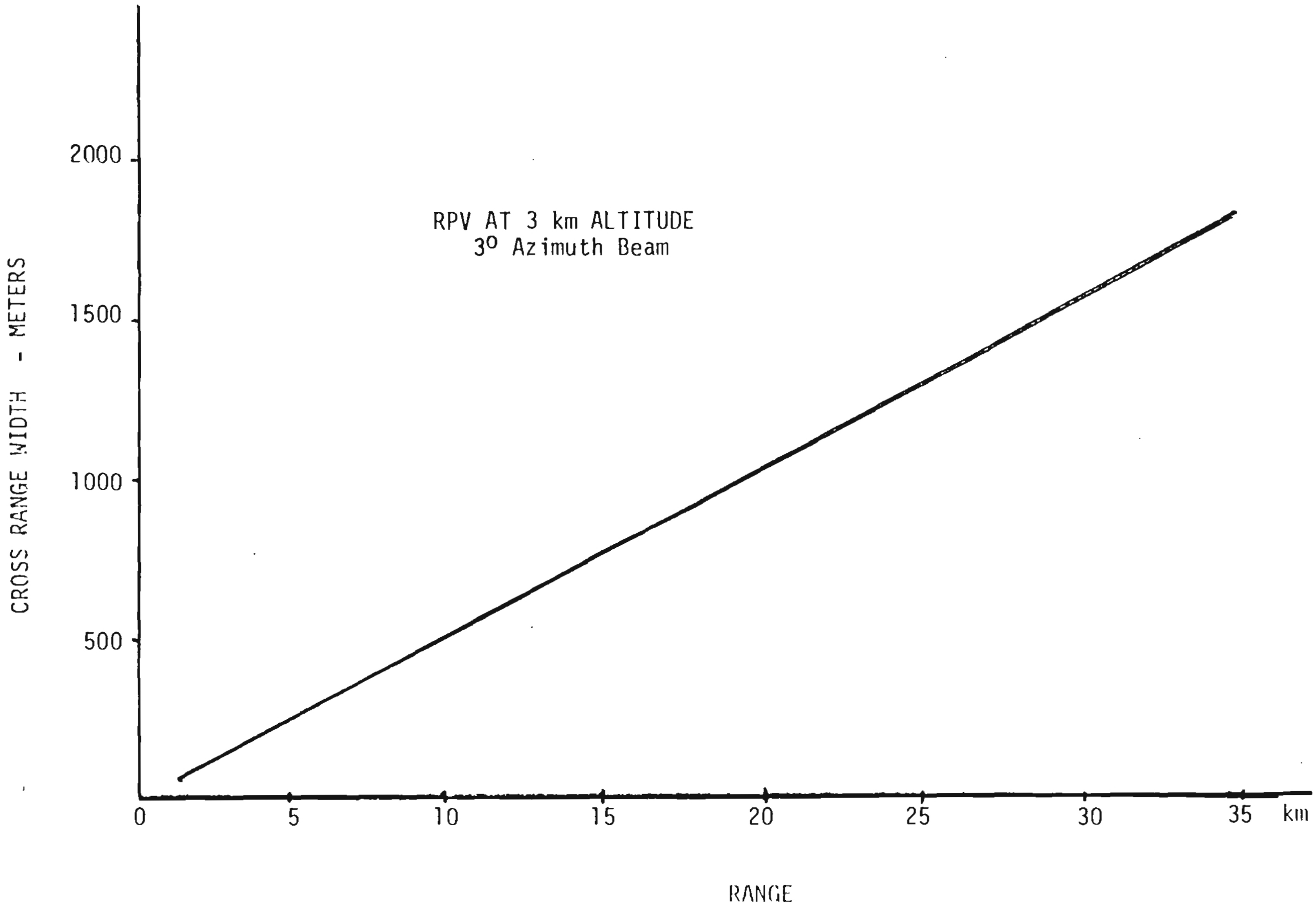

Figure 4. Cross range resolution for RPV.

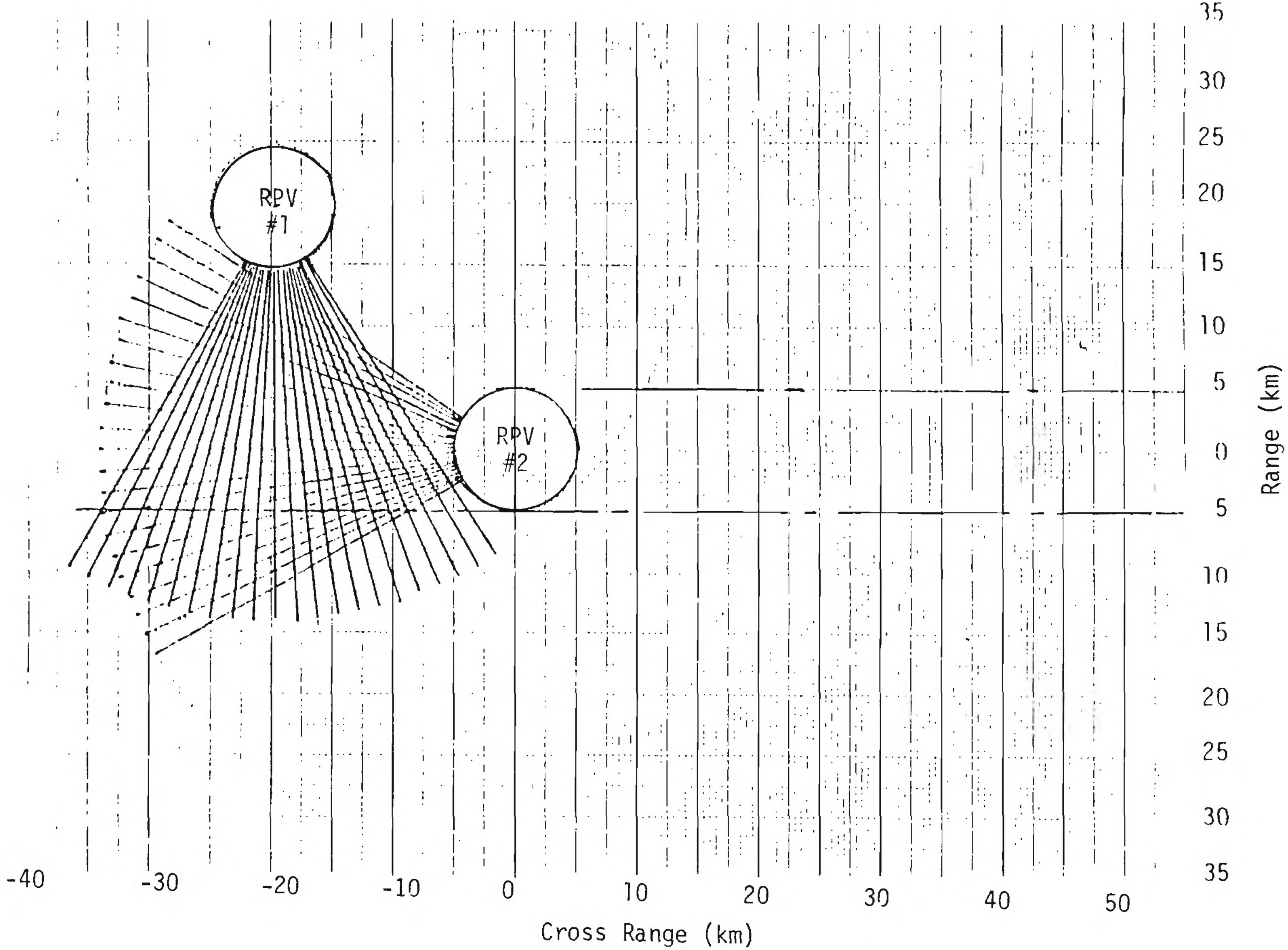

Figure 5. Two PRVs scanning at right angles.

spatial baseline reference. A minimum amount of preflight planning is required to identify coordinant reference targets and set the flight paths so that the reference targets will be observed from perpendicular directions. The data can be stored in the ground based computer and adjusted for registration of the fixed reference targets. The resulting strip map would be high resolution radar data.

3.6 DISPLACED PHASE CENTER (DPC)

DPC processing is a means of compensating for aircraft motion in airborne MTI processing. It involves generation of a velocity compensation vector which is then added to the phase-detected video to remove effects of platform motion. DPC is more accurate than clutter tracking and velocity estimation schemes, and may be useful when detecting targets having low radial velocity.

The classical implementation of DPC utilizes a segmented aperture (often a monopulse antenna) to generate a delta signal which is used to compensate for platform motion. The HOWLS antenna could be used for such processing, but the mechanically scanned system has no such monopulse capability. If DPC in the RPV scenario is desired, the mechanically scanned antenna must be modified for monopulse capability.

SECTION 4
TEST FACILITY ORGANIZATION AND COSTS

4.1 ORGANIZATION

The role envisioned for the Airborne Test Facility will require the dedication of a number of people from several different technical areas. It is the feeling of the study group that a dedicated organization should be established to handle test bed activities to efficiently carry out the tasks planned for the test bed. This organization should have specific personnel assigned to it and should have identified, committed funds to support its activities.

The test bed support group could be located either within the existing organization or could report directly to the director of the CS&TAL. In either event, a full-time head of the group should be assigned who should be responsible for maintenance and operation of equipment, planning for use of equipment, conduct of experiments, and interpretation of the resulting data. He should be supported with a full time dedicated staff adequate to support the facility, and funds for personnel, support contracts, travel, and equipment should be provided.

The study group feels rather strongly that adequate support of the facility is crucial to its successful utilization and that implementation of the facility should not be undertaken if such support is not available.

4.2 PERSONNEL

4.2.1 INTRODUCTION

The airborne test facility requires planning, maintenance and operation of complex equipment, and reduction and interpretation of complex recorded data. A number of personnel having a range of expertise are necessary to support such activities.

As discussed above, a group leader should be assigned who will have full responsibility for maintenance of equipment, planning and conducting field operations, and interpretation of data. The largest support requirements are for operation and maintenance of the ground and aircraft equipment, but support for planning and data analysis is also required.

4.2.2 AIRBORNE RADAR SUPPORT PERSONNEL

Based on current Lincoln Laboratory practice and our best estimates, it is felt that three people will be required to support and operate the equipment in the aircraft. These three people should consist of an operations and maintenance engineer contracted from GE, along with one additional radar engineer and one technician to adequately support the airborne radar.

4.2.3 GROUND VAN SUPPORT PERSONNEL

Support of the van and its attendant data reduction capabilities will require approximately 6 1/2 people:

- 1 Programmer for the MODCOMP computer
- 1 Programmer for the Programmable Signal Processor (PSP)
- 1/4 - 1/2 Digital Hardware Engineer
- 1 Radar Systems Engineer
- 1 Radar and Software Engineer
- 1 Junior Engineer (responsible for van support and general coordination)
- 1 Technician and Data Librarian

4.2.4 ADMINISTRATION AND PLANNING PERSONNEL

Careful planning of the use of the facility is crucial to its success. The head of the group will be responsible for both immediate and long-range plans for the use of the facility, and will be supported by the radar engineers from the aircraft and from the ground based van. In addition, it is suggested that approximately one-half time of a senior radar system engineer be made available to support such planning functions. Support by a full-time secretary will probably be required.

It should be emphasized that these personnel estimates approach the "bare bones" level and reduction of these estimates by more than two people will not only seriously impact the ability to efficiently conduct experiments, but may well result in the inability to operate the test bed at any level.

4.3 EQUIPMENT TRANSITION

The transition of the facility from Lincoln Laboratory, to the Army involves not only the transfer of equipment, but also the transfer of technology and experience as well. It is estimated that to bring competent, experienced people to the level where they will be able to operate equipment and maintain software will require from six to eight months, and such a time lag must be included in facility plans.

The actual transfer of equipment should require a short period of time. However, installation of equipment in a different aircraft will require two months planning, one month for actual transfer, and from one to two months to restore the system to reliable operating condition.

4.4. OUTSIDE SUPPORT CONTRACTS

A portion of the personnel identified in Section 4.2 may be supplied from outside organizations, such as General Electric or Lincoln Laboratory, particularly during the transition phase. In addition, the following support contracts will be required:

CONTRACTOR	AMOUNT	FUNCTION
RAM TECH	$6K/yr	Support of displays
STC	$17K/yr	Maintenance
MODCOMP	$26K/yr	Computer-maintenance
Westinghouse	$30K/yr	Hardware and software support for PSP
GE	$140K/yr	$110K for O&M Engineer for airborne radar identified in Section 4.2; $30K for spare and repair parts for airborne radar

If it is decided to continue aircraft rental under the existing agreement, this will cost approximately $115K/yr. General test equipment purchase, calibration and repair costs will probably run about $100K/yr.

In the event the field operations are to be conducted at other than the Ft. Monmouth area, additional costs which vary with location will be incurred. Rough estimates for four months of field operations would be $30K for travel and $100K for range support costs.

4.5 AIRCRAFT POSSIBILITIES

Three alternatives for the airborne platform exist, including continued use of the aircraft, outright purchase of the aircraft, and installation in an Army helicopter.

While purchase as opposed to continued rental may appear to be attractive at first glance, it is felt the requirements for providing pilots and maintenance would represent an unnecessary and undesirable burden on the program management. In addition, there are some questions as to the payload capacity of the present aircraft and if any additional equipment is to be added for future tests, then the present aircraft will be weight limited.

As discussed in earlier paragraphs, continued rental of the fixed-wing aircraft represents a substantial program expense, but the transfer to a helicopter represents a cost to the program in time for installation and restoration of the equipment to full operating condition.

There are also some technical problems associated with a helicopter installation, including the fact that helicopters normally pitch forward during level flight and there are problems with a belly-mount of the antenna to avoid obscuration by the landing skids. Nose or pod mounting of the antenna should receive some consideration. The reduction in direct costs associated with the use of an Army helicopter should be weighed against the probable 4-6 month interruption in equipment availability during and following installation.

4.6 RESOURCE SUMMARY

Resources required for support of the airborne test facility are summarized below. Unless resources at this level are committed to the program, chances of achieving the technical goals are quite small.

Personnel:	Management and Planning	1.5 people
	Airborne Radar Support	3 people
	Ground Van Support	6.5 people
Support Contracts (Includes services for one O&M Radar Engineer identified above)		$219K
Aircraft Rental		$115K/yr
Field Operation Costs		$130K/yr
Equipment Costs		$100K/yr

SECTION 5

POTENTIAL SOURCES FOR SUPPORT

5.1 ARMY PROGRAM MANAGERS/OFFICES

The U.S. Army has several airborne radar systems ranging from the engineering development stage (HAWFCARS) to field operational stage (APS-94). These systems are operating in the frequency range from 10 GHz to 35 GHz. The mission use is from fire control to long range (100 km) area surveillance. It is desirable for all of these systems to have the capacity to detect and classify moving as well as stationary targets. Performance must be day or night and in adverse weather and with battlefield polluted crud and obscurants.

Phenomena of naturally occurring radar scattering appears to be a linear function of frequency between 10 and 35 GHz. Thus, any measurements, observation or demonstrations made at 16 GHz can be scaled up or down in frequency and with confidence that the phenomena observed at K_u-band can be translated and modelled at X- and K_a-bands. This will permit the airborne test bed to be used with confidence in support of tests for programs such as E-SCAN, SOTAS, RPV, HAWFCARS, and FOPEN.

The HOWLS radar can be used in a data collection mode to compare the operational differences between using coherent and non-coherent transmissions; difference between spread spectrum of 500 MHz and frequency hopping over the same bandwidth; the radar scattering dependence as a function of depression or grazing angle of ground clutter as well as man-made objects; the effects of vertical wind shear on rain backscatter; and since the system is highly mobile, many types of ground clutter can be investigated. Since the system is mobile, effects of seasonal changes such as snow covered vegetation, ice, fog, falling snow, coastal and radiation generated fog can be obtained where and when the phenomena occur.

The advantages of aquiring sensor data and cueing concepts for ground based systems such as DIVADS, AFCORS, SHORADS, and NURADS can be demonstrated with the airborne test bed radar.

Highly calibrated data can be collated to provide better modelling and insight into the effectiveness of small projectiles, rockets, and missiles being developed for CAWS, MLRS, ASSAULT BREAKER, TANK BREAKER, WAAM and other munitions. The wideband data link will provide the opportunity for the ground based crew to determine what a smart weapon will detect in the emulated field of view.

The airborne test bed should be configured such that future target classification and identification observable functions such as Spatial Phase Resonance, Polarization Matrix, and Vibrational Doppler can be investigated.

Properties of material such as dielectric constant, reflectivity, and transmissivity can change with frequency. Material change along with shape sensitivity to radar wavelengths which are comparable to object size prevents the radar designer from making linear scaling assumptions of clutter and target scattering characteristics where large changes in the radar operating frequencies are proposed. It is highly recommended that space be provided on the airborne test platform for IR, Millimeter Wave (MMW), and UHF sensors as well as the K_u-band sensor. In this way, real time comparisons can be made of the operational range in adverse weather and battlefield crud. With radars operating at widely separated frequencies, it will be possible to evaluate the ability to penetrate foliage, evaluate atmospheric losses, compare high resolution imaging systems with low resolution queing systems, clutter masking, and target signatures.

Not only will the test bed radar serve as a calibrated data collection system, but also emulation of techniques can be demonstrated in real battlefield type scenarios. Thus the airborne radar test bed can and should be a major support for U.S. Army Program Managers involved with radar sensors.

5.2 DOD PROGRAMS

Every user of electronics equipment would like for the equipment to fit into the smallest possible space, weigh the least number of pounds, consume almost no prime power, and perform functions in real time with minimum delay. The RPV radar will have limited space and weight established by the capability of the platform to carry the radar. For the operational data collection of the battlefield scenario postulated for the RPV, the weight and size restrictions will limit the capability of the radar unless some new technology is brought to bear on the radar configuration.

The very high speed integrated circuit (VHSIC) program should provide a major significant reduction in computer size and weight for application in the RPV radar. The more signal processing which can be done aboard the RPV to identify and locate prime targets of interest, the smaller amount of data that need be transmitted to the ground station, putting smaller demands on the data link between the RPV and the ground station.

Present state-of-the-art in VHSIC is to perform a single computer logic one step operation in one nanosecond and to process data through a bandwidth of 85 MHz at 10 M bits per second. The airborne test bed will be an ideal unit to provide testing of VSHIC units to perform data processing, communication link formating, and signal waveform management in real time with real radar signals in an emulated battlefield scenario.

SECTION 6
SUMMARY

A group consisting of Major (Dr.) E. K. Reedy, Dr. G. W. Ewell, and Dr. R. D. Hayes met during the period 5-16 October 1981 to review plans for the CS&TAL Airborne Test Bed. The group reviewed a number of pertinent documents and interviewed a number of personnel, both from CS&TAL and from Lincoln Laboratories. This report represents the summary of the findings and recommendations of this group.

The first section sets the scenario for the problem, while the second section establishes priorities and objectives. The operation priorities of detection of ground movers, aircraft and ground sitters are discussed, and technology issues for short, intermediate and long term goals are established.

Questions of hardware adequacy for stationary target detection, synthetic aperture technology, and tracking and measurement are then addressed, and areas where modification to the test bed may be required are identified.

The questions of organization and management are addressed in Section 4, including staffing, training and budget requirements. Finally, Section 5 identifies some potential sources of support for the test bed.

The group feels that the airborne test bed is a useful facility and one which will enhance the technical capability of CS&TAL. It also recognizes that the equipment is complex and will require a substantial investment in personnel and funding to have a useful facility. The group feels <u>strongly</u> that the test bed should not be implemented unless adequate support is made available to efficiently maintain the equipment, plan and carry out field operations, and analyze and interpret the resulting data.